LIB CHARGER INTERFACE DEFINITION DOCUMENT

For the

EMU LITHIUM ION BATTERY SYSTEM

Date: *Aug 17 2006*
Contract Number: NNJ04HA05C
DRL/DRD 4

LIB Interface Definition Document
for the
EMU Lithium Ion Battery System

Prepared by:

_____

Date

Approved by:

_____

James K. Jacobs *Date*
Project Manager

_____

James K. Jacobs *Date*
Chief Technology Officer

Change Record

Rev.	Date	Originator	Description
A	9 Dec03	Electrovaya	Preliminary for PDR
B	10 Sept 04	Electrovaya	Presentation at CDR
C	25 Mar 05	JK Jacobs	Title changed. Cable pin-outs changed. Minor changes to description of functionality. Front and rear panel legends changed. Minor textural changes made to improve clarity.
D	June 16 2006	Eric Darcy	Update 2.1 Document to current revision Update 3.1 to include physical dimension verification Update 3.2 mass < 9500 gm
E	Aug 17 2006 ECN87	F Davies	add SSP 50005, JPG 8080.5, standard G-41 and JSC 28322, Standard NC40 to applicable documents list

Table of Contents

1. INTRODUCTION

1.1 Purpose and Scope

This document defines the functional interface engineering requirements for the Lithium Ion Battery Charger for use in charging, discharging and testing the LIB that is itself intended for use in powering the Extravehicular Mobility Unit (EMU) Primary Life Support Subsystem (PLSS). The purpose of this document is to establish and maintain compatibility between the LIB Charger and its co-functioning items. These items include the PLSS, the LIB, and the Station/Shuttle.

1.2 Responsibility and Change Authority

This document is prepared and maintained in accordance with Electrovaya's Configuration Management Plan. The responsibility for the development of this document lies with the Electrovaya Engineering group. Change authority is Electrovaya with NASA concurrence.

2. APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this ICD to the extent specified herein.

Document Number	Revision/ Release Date	Document Title
JSC-29927	Current revision	Lithium-ion Battery (LIB) Charger, GFE End Item Specification
JSC-29928	Current revision	Lithium-ion Battery (LIB), GFE End Item Specification
200EC403	Current revision	Electrovaya Configuration Management Plan
100EQ098	Current revision	Electrovaya Quality Manual
NSTS 5300.4 (1D-2)	Current revision	Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program
SSP 41173B		Space Station Quality Assurance Requirements
SSP 30233F		Space Station Requirements for Materials and Processes
JSC 27301D		Materials Control Plan for Johnson Space Center (JSC) Flight Hardware
SSP 50005	Current revision	International Space Station Flight Crew Integration Standard

JPG 8080.5 , standard G-41	Current revision	JSC Design and Procedural Standards Manual
JSC28322, standard NC40	Current revision	ISS Acoustic Requirements and Testing Document for ISS Non-Integrated Equipment

2.2 Reference Documents

The following documents are reference documents utilized in the development of this ICD. These documents do not form a part of this plan and are not controlled by their reference herein.

Document Number	**Revision/ Release Date**	**Document Title**

2.3 Order of Precedence

In the event of a conflict between the text of this document and an applicable document cited herein, the text of this document takes precedence. All specifications, standards, exhibits, drawings or other documents that are invoked as "applicable" in this specification are incorporated as cited. All documents that are referred to by an applicable document are considered to be for guidance and information only.

3. MECHANICAL INTERFACES

3.1 General and Dimensional

The LIB Charger is configured as a 'free floating' box, suitable for mounting in a variety of locations and orientations, depending on the situation of use. Since LIB charging may be effected with the LIB in or out of the PLSS, the mechanical interface with the LIB is flexible. Two arrangements are recognized: LIB mounted in the PLSS, the Charger mounted on a convenient surface, and the electrical connection between the two made with a flexible 12-foot

cable; LIB mounted adjacent to a side of the Charger and secured with cloth straps, the electrical connection made with a short cable. These cables plug into the rear of the charger.

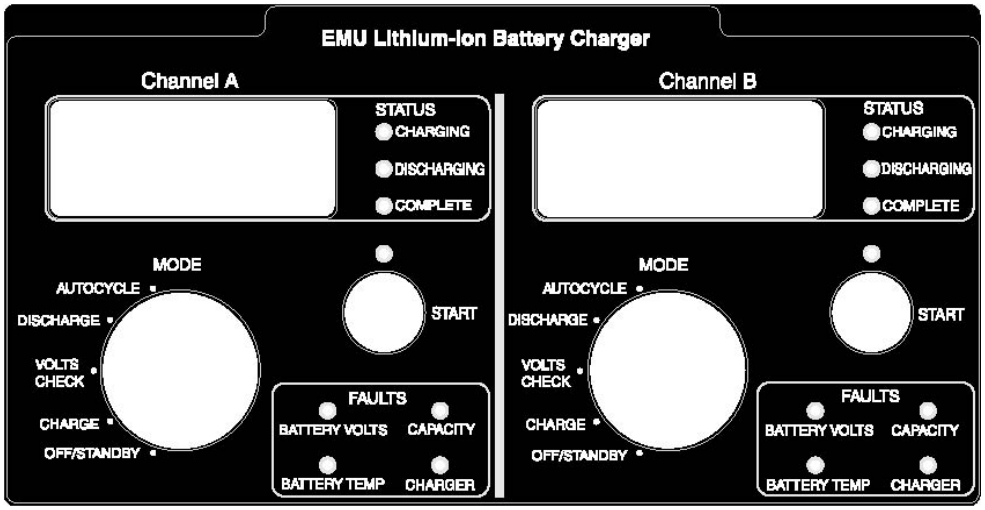
The LIB Charger is functionally a pair of identical chargers that operate independently. Thus, in each of these two mechanical arrangements there may be a second LIB involved. The two LIBs may have varying attachments – one may be secured to the charger, while the other remains in the PLSS, connected with the longer cable. With two long cables, two LIBs in two EMUs can be charged at the same time.

The LIB Charger comprises an electronics box containing the pair of chargers, two 12-foot charger cables, two detachable power cords (one for 28VDC supply, the other for 120VDC supply), and a soft-goods pouch which can be mounted on the top of the electronics box to contain the cables and extra fuses.

Power is supplied to the Charger with a flexible line cord, again allowing flexibility of location. Mounting of the Charger to cabin surfaces may be effected with Velcro pads.

Under some circumstances, the Charger may be used as a 'Discharger,' removing LIB-stored energy and dissipating it as heat. If this is done, then the heat release from the Charger may be a consideration in its location. Neither of the air intake vents on the sides of the charger, nor the air exhaust vent at the rear of the charger, should be blocked.

Overall views of the front and rear of the charger are shown in the figures below, including both detailed panel text, and overall views of the charger connected to a pair of LIBs. Following these images is a figure showing overall dimensional envelopes.



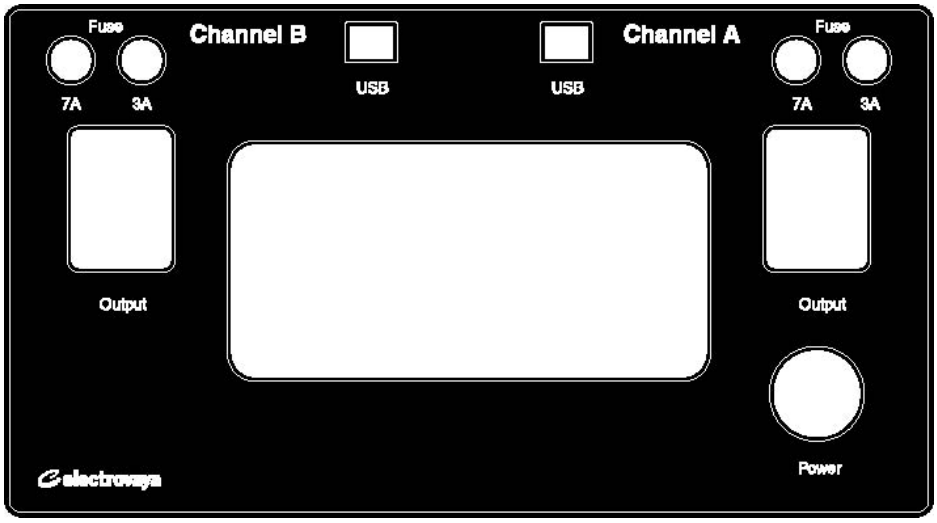

Fuse
7A
3A
Channel B
USB
USB
Channel A
Fuse
7A
3A
Output
Output
Power
electrovaya

Figure 1

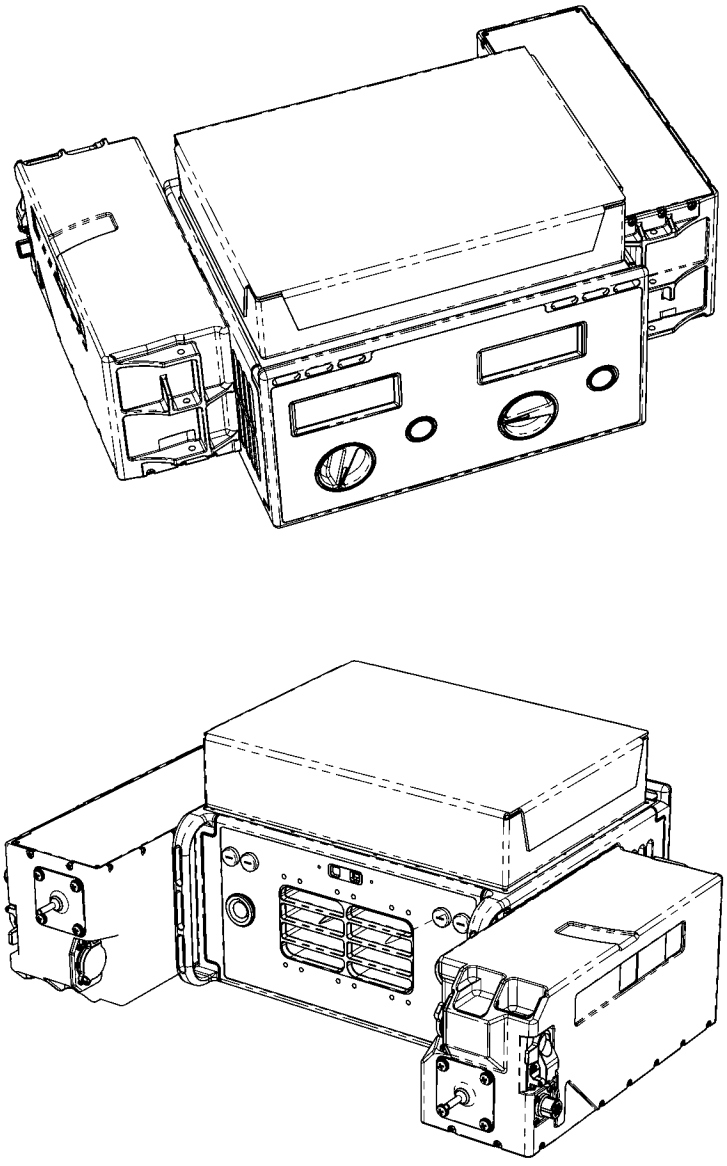


Figure 2

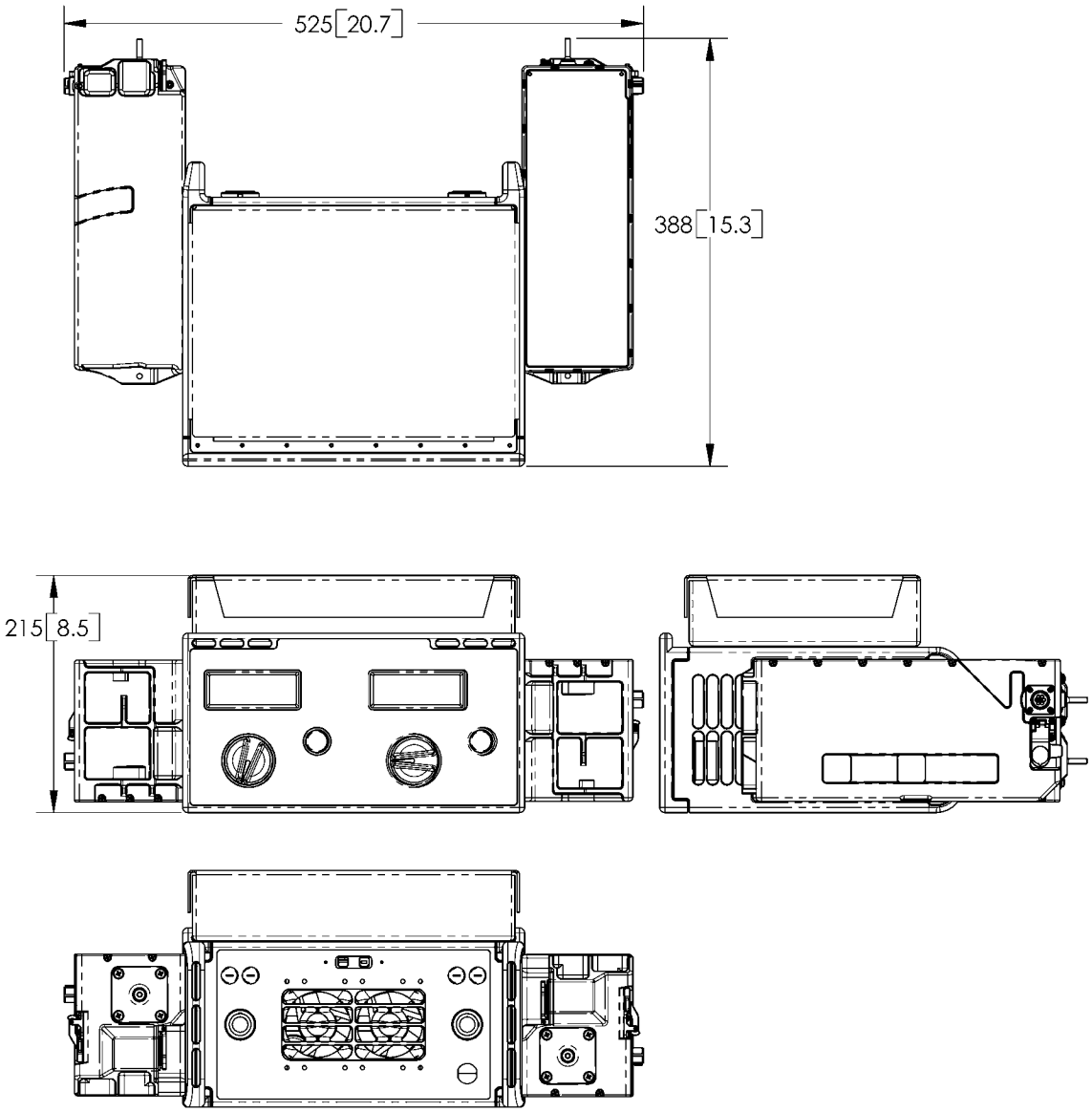


Figure 3 (Dimensions in mm [in])

Dimensional verification for charger

Height: The height excluding protrusions such as screw heads, velcro pads/mounting bumps, and lip above LCD displays shall be not greater than 151 mm.

Width: The width excluding velcro straps and associated rings shall not be greater than 311 mm.

Depth: The depth shall not be greater than 311 mm

3.2 Mass

The mass of the LIB Charger is not to exceed 9500 grams excluding the cables and soft-goods pouch. The center of gravity, not including the cables and soft-goods pouch is near the geometric center of the electronics box.

3.3 Acoustics

The LIB Charger contains DC/DC converters, and two small fans. Both types of device are potential noise generators. In the audible range the major source of noise is the air noise from the fans. The LIB charger complies with the Acoustic Noise Criteria in JPG 8080.5, Standard G-41 and JSC 28322, Standard NC40.

4. ELECTRICAL INTERFACES

4.1 Power consumption

The LIB charger draws less than 230 W from a 28Vdc power outlet and less than 550 W from a 120V dc power outlet.

4.2 Power quality

The LIB Charger meets all the 28 Volt Power Quality Specifications as stated in SSP 52051, Volume 2 and NSTS-21000-IDD-ISS. The LIB Charger meets all the 28 Volt Power Quality Specifications as stated in NSTS-21000-IDD-MDK. The LIB Charger meets all the 120 Volt Power Quality Specifications as stated in SSP 52051, Volume 1 and NSTS-21000-IDD-ISS.

4.3 Power Connectors

The power connector at the rear of the charger can be connected to either a 28VDC cable or to a 120VDC cable. The pin-out of the rear-mounted receptacle (J1) is as follows:

Rear Panel Connector: D38999/26FD5SN

A	GND
B	+28VDC
C	Return (either 28 or 120)

D	NC
E	+120VDC
shell	GND

4.4 Isolation, grounding, bonding

The charger is a free-floating component. Its ground reference is supplied from its power supply cable. Battery charging power is entirely isolated from supply power. The case of the Charger is at reference ground, as are the extension cable shields when connected to the Charger. All exterior surfaces of the charger are bonded in accordance with SSP30245RC for an H-bond specification..

4.5 Power modes

The charger has five power modes of operation, independent for each channel: Standby - no current passes between the charger channel and the LIB connected to it, and the charger channel draws less than 8mA of current from the power line; Charge – charge current passes between the charger channel and the LIB connected to it and power to charge the LIB is drawn from the power line; Volts Check – intermittent discharge current passes between the charger channel and the LIB connected to it and current is drawn from the power line to power the Charger internal loads (fans, display, lights, etc.); Discharge – discharge current passes between the charger channel and the LIB connected to it and the charger channel draws current from the power line to power the Charger internal loads; Autocycle – this is an automated combination of the charge and discharge modes. Should the Charger become disconnected from the power line during operation, each channel will draw power from any LIB connected to that channel to continue operation. It cannot, of course, continue to charge an LIB without line power.

4.6 Communications

Each charger channel is provided with an independent communications port meeting the USB 1.1 protocol. The charger uses type B (smaller square, not flat-rectangular) connectors. Two USB cables (type B plug-to-type A plug) are included in the cable set, and housed in the soft-goods pouch.

4.7 LIB Connection

Each charger channel has an electrical interface to a Lithium Ion Battery through a panel-mount connector (one for each channel) on the rear of the Charger. Pin-outs are as follows:

Table 1

Type:	Lemo EGJ.4B.310.CYB	
Pin #	**Use**	Remarks
1	Cell 2	
2	Cell 3	
3	Cell 4	
4	Cell 5	
5	GND	Chassis ground connected to charger case
6	Thermistor	
7	Battery Ground	
8	Cell 1	
9	Battery Power Return (-)	
10	Battery Power (+)	
Shell	GND	Chassis ground connected to charger case

4.8 Operation Functionality

Operating mode functionality is as follows:

Charge Mode

In this mode the charger delivers electrical energy to the LIB until the LIB is completely charged, as defined in 3.2.2.2 of JSC-29928. The LIB is determined to have been fully charged when the maximum LIB cell module open-circuit voltage reaches at least 4.090 volts and the minimum LIB cell module open-circuit voltage is at least 4.050 volts. An LIB which has been discharged to its rated capacity, and the cells of which are nominally in charge balance can be fully charged within 8 hours if the charger is powered from 120VDC. This mode has the following features:

a. When the LIB is completely charged, the charger indicates this by illuminating the "complete" status LED.

b. While the LIB is charging, the charger indicates this by blinking the "Charging" status LED.

c. If the LIB temperature exceeds the maximum normal charge temperature (40°C, 104°F) or is less than 10°C (50°F), the charger displays the battery temperature and a fault light. Operation is not affected.

Volts Check Mode

In this mode, the charger display shows the open circuit voltage of the LIB and the voltage of each LIB cell module. The display unambiguously indicates if no LIB is connected.

a. When the Push-to-start button is pressed in the VOLTS CHECK mode, a 9A or similar resistive load is applied to the battery for 5 seconds. While the 9A or similar resistive load is connected, the voltage display tracks the battery voltage.

b. When the 9A or similar resistive load is disconnected, the last (lowest) voltage is latched and displayed on the voltage display until the mode select switch is changed or the Push-to-start button is pressed again.

c. A wait time of 100 seconds is required before a subsequent Volt Check can be conducted. This allows the load resistor to cool and the LIB to recover.

Autocycle Mode

In this mode the charger completely discharges the battery, fully charges it, then completely discharges it again, and finally charges it to a capacity of 10Ah.

a. The charger displays the capacity removed from the LIB during the second discharge after completion of the autocycle.

b. The charger performs the complete Autocycle in less than 74 hours when using 120V dc input power and in less than 84 hours when using 28V dc input power. Actual duration depends on the state of charge of each LIB. This can be accomplished with up two LIBs simultaneously.

c. This mode will be used to determine the full capacity of an LIB when uncertainty arises.

Discharge Mode

In this mode the charger removes energy from the battery until it is fully discharged. An LIB is fully discharged when either the minimum cell module voltage is less than 3.0 volts, or the LIB voltage is less than 16 volts. A complete discharge can be accomplished within 32 hours.

a. The charger displays the capacity removed from the LIB during the discharge.

5. HUMAN FACTORS

5.1 Front and rear Panels

The front and rear panel configurations are shown in Figure 1 (above). The front and rear panels are divided into two sections, one for each of the two channels. On the front panel the numerical display is via a 4-line x 20 character LCD alphanumeric display for each channel. Cooling-air intake grilles are located on the left and right sides of the front panel. Cooling air exhaust is from the center of the rear panel. Battery (LIB) connectors, power connector, USB connectors, and fuses are located on the rear panel.

Mode selection switch:

This rotary switch has the following 5 clockwise-ordered positions listed below.

Mode switch positions:
OFF/STANDBY
CHARGE
VOLTS CHECK
AUTOCYCLE
DISCHARGE

Front Panel LEDs

The charger flashes all LEDs on for approximately 1 second (a lamp check) when the mode select switch is turned away from the OFF/STANDBY position. LED assignments are in accordance with the LED table below.

Note: LED colors do not necessarily comply with SSP 50005 9.5.3.2

LED table:

Name:	Color	Notes:
Push-to-start LED indicator	White	Continuous on when Push-to-start switch is pressed. Goes off when Mode selection switch is changed.
Status LED: Charging	Yellow	Blinks when battery is charging
Status LED: Discharging	Orange	Blinks when battery is discharging
Status LED: Complete	Green	Continuous on when the selected mode terminates normally.
Fault status LED: Capacity	Red	Continuous on when individual cell module states of charge are more than 2AH out of balance.
Fault status LED: Voltage	Red	Continuous on when battery voltage is above maximum or below minimum under any mode except OFF/STANDBY.
Fault status LED: temperature	Red	Continuous on when battery is greater than 40°C (104°F) or less than 10°C (50°F).
Fault status LED: Charger	Red	Continuous on when Charger detects a control failure or is without line power.

Display:

The front panel display of the LIB charger has the following features:

a. The status display indicates the mode of the corresponding charger channel. The modes are indicated as described in the table below.

Mode switch position:	Method of indication:
STANDBY	display is completely off
CHARGE	Word CHARGE appears on display
VOLTS CHECK	See requirements of VOLTS CHECK mode
AUTOCYCLE	Word AUTO appears on display
DISCHARGE	Word DISCHARGE appears on display

b. The voltage display has a resolution of 0.01V an accuracy of +/-0.3V and updates every 0.5 seconds.

c. The current display has a resolution of 0.1A an accuracy of +/-0.1A and updates every 0.5 seconds. When the current is set to zero by the charger, the display reads zero.

d. The capacity display has a resolution of 0.1Ah an accuracy of +/-0.25Ah and updates every 0.5 seconds.

e. To differentiate between discharge and charge, ampere-hours and current are displayed as a negative value for discharge.

f. In the VOLTS CHECK mode, the five cell module voltages are displayed.

g. Upon power up, the LIB Charger displays the ampere-hours of the last cycle. When the start switch is activated the active data is displayed.

h. When the selector switch is turned from OFF/STANDBY to any other mode, the display runs a pixel check and displays its firmware version.

i. A "heartbeat" indicator (alternating '**<**' and '**>**' signs in the upper left corner of the display) operates with about a 2-second pulse whenever the display data is being updated properly. The update rate is faster than the heartbeat blink rate.

Start Button.

The Start button is recessed to preclude inadvertent activation.

The Mode select switch, Start button, and Start LED function together as follows:

a. The Start LED goes out when the Mode select switch is turned to a different position.

b. The Start LED illuminates when the Start button is pressed and the Charger starts the selected mode, unless the Mode select switch is in the OFF/STANDBY position.

c. The Start button when activated, starts the function selected on the Mode select switch for all modes except the OFF/STANDBY mode.

d. If the LIB is disconnected from the charger, the Start LED goes out (and the current mode is terminatd).

6. THERMAL INTERFACES

6.1 Heat Release

The Charger generates considerable waste heat. This is delivered to the cabin air. During discharge of two LIBs (worst case) 60 watts (30 watts per channel) may be delivered in the exhaust air stream. The discharge load within the charger is a constant resistance; as the battery voltage decreases during charge the power delivered decreases commensurately. Exhaust air temperature will not exceed 45ºC under worst-case hot operating environment. In other modes of operation, up to 20 watts per channel (total 40 watts) may be delivered. The exhaust grille is located at the back of the charger. The charger should be located so that neither of the intake grilles nor the exhaust grille is obstructed.

The charger is designed to maintain the temperature of exterior surfaces below 45ºC (touch temperature). Interior surfaces may be hotter in operation.

6.2 Operating Temperature Range

The Charger is designed to operate in the temperature range of 10ºC (50°F) to 32.2ºC (90°F) ambient air and at an ambient pressure of 8.2 to 14.7 psia.

7. ENVIRONMENT

7.1 Operational Environment

The LIB is designed to operate within the limits of the environment specified in the LIB End Item Specification (EIS), JSC29927.

Abbreviations and Acronyms List

°C	Degrees Celsius
°F	Degrees Fahrenheit
A	Ampere
AC	Alternating Current
ADC	Analog-to-Digital Converter
Ah	Ampere-Hour
ANSI	American National Standard Institute
ALPS	Air Lock Power Supply
ASCII	American Standard Code for Information Interchange
BCA	Battery Charger Assembly
BIOS	Basic Input/Output System
CDR	Critical Design Review
COSMOS	The name of a finite element analysis software
COTS	Commercial off-the-Shelf
CR	Change Request
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
DAC	Digital-to-Analog Converter
DC	Direct Current
DR	Discrepancy Report
EEE	Electrical, Electronic and Electromechanical
EEPROM	Electrically Erasable Programmable Read-Only Memory
EIS	End Item Specification
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
EVA	Extravehicular Activity
FCE	Flight Certified Equipment
FET	Field Effect Transistor
GCAR	Safety and Mission Assurance Certification Approval Request
GFE	Government Furnished Equipment

gm	Gram
ICD	Interface Control Document
in	Inch
I2C	Inter-Integrated Circuit (a communications protocol)
ICE	In-Circuit-Emulation
ICP	In-Circuit-Programming
ISO	International Organization for Standardization
ISS	International Space Station
ITMG	Meteorite protection garment
J	Joule
JSC	Johnson Space Center
K	Kelvin
kg	Kilogram
KSC	Kennedy Space Center
L	Liter
LED	Light Emitting Diode
LIB	Lithium Ion Battery
LSB	Least Significant Bit
m^2	Meters squared
mΩ	Milliohm
MIL-STD	Military Standard
min	Minute
mm	Millimeter
ms	Millisecond
MSFC	Marshall Space Flight Center
MUA	Material Usage Agreement
NASA	National Aeronautics and Space Administration
OCV	Open Circuit Voltage
OS	Operating System
PC	Personal Computer
PCB	Printed Circuit Board ?
PDR	Preliminary Design Review

PIC14000	Microchip Technology Inc.'s Programmable Interrupt Controller
POR	Power-on Reset (of a microchip)
PLSS	Primary Life Support Subsystem
PRACA	Problem Reporting and Corrective Action
PVG	Pack Voltage Good (logic signal)
QMS	Quality Management System
RAM	Random Access Memory
RDMS	Risk Data Management System
S&MA	Safety and Mission Assurance
SDP	Software Development Plan
sec	second
SEE	Single Event Effects
SR&QA	Safety, Reliability, and Quality Assurance
SRS	Software Requirement Specification
SS	Space Shuttle
SSP	Space Station Program
TBD	To Be Determined
USB	Universal Serial Bus
V	Volt
VC	Visibly Clean
VDC	Direct Current Voltage
W	Watt
WDT	Watchdog Timer